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Comparison of renewable energy policy evolution among the BRICs

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ABSTRACT

Renewable energy policy evolution of the BRICs is analyzed and assessed quantitatively based on the Bai and Perron' s structure breaks test. Results indicate no break for time series of renewable production in Russia, while series of renewable production and consumption are characterized as segmented trend stationary processes around one or two structural breaks in Brazil, India and China. Renewable policies in Brazil and China have long-term positive effects on renewable energy production and consumption, improving the two variables' growth rate. The time series structure change of Indian renewable energy production is complicated and the long-term impact of energy policies on renewable production is contradictory at the two breakpoints. Russian renewable policies are not working, reducing renewable energy consumption growth in the long-term. Empirical analysis suggests policy implications that China should mandate the promotion of renewable energy, develop biomass energy on the base of comparative advantage and enhance renewable energy industry chain integration.

Contents

1. Introduction

Advancing renewable energy development is the effective approach to address energy security and climate change. Currently, the US, Japan, Brazil and other countries have listed development of renewable energy as an important strategy for the future.

Among the major energy production and consumption countries in the world, Brazil, Russia, India and China (the BRICs) take a pivotal position in the global economy, thus renewable energy policies formulation and implementation is especially noteworthy. In terms of influence on the world economy, the BRIC economies had an average growth rate of 10.7% from 2006 to 2008. In 2009, the GDP of the four countries accounted for 15.2% of the world, and the volume of trade accounted for 12.8%, whose contribution to world economic growth rate is over 50% according to Purchasing Power Parity. As for the energy production and consumption, the energy production of the BRICs was 30.00% and 31.29% of the

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world energy production in 2006 and 2007, and correspondingly, the energy consumption was 27.32% and 27.24%, respectively.

As the pivotal production and consumption countries in the world, the BRICs attached great importance to the development of renewable energy, and successively formulated series of long-term and directional strategic measures to address the renewable energy issues. For instance, Brazil, one of the earliest countries planning renewable energy, promulgated Pro-Alcohol Program, Brazil's Biodiesel Production and Use Program, issued 11097 and 11116 Executive Order, and developed tax policies to support capital and credit in renewable energy production. Russia formulated The Concept of Russian Energy Policy in New Economic Conditions, Main Directions of Energy Policy of the Russian Federation until 2010, and Energy Strategy of Russia until 2020, Elaboration on Main Provisions of Energy Strategy of Russia until 2020 constantly since 1992. In 2009, Russian Premier Vladamir Putin approved Electricity Sector on the Basis of Renewable Energy Sources for the Period up to 2020, further establishing technical indicators of renewable energy development. The Indian government also issued The Energy Conservation Law of 2001, The Electricity Act of 2003 and The Integrated Energy Policy Report of 2006 sequentially, so as to strengthen research and promotion practice of fan manufacturing, solar thermal, small hydropower, biomass and other renewable energy technology. Beginning from the mid-1980s, China enacted Recommendations on the Seventh Five-year Economic and Social Development Plan, Renewable Energy Law, Middle and Long Term of Renewable Energy Development, China's Policies and Actions on Climate Change, Renewable Energy Industrial Development Guidance Catalogue, and The Emerging Energy Industry Planning to promote the development and utilization of renewable energy.

In the BRIC countries, China and India are rich in coal and poor in gas and oil, and their energy production and consumption structure are similar to each other; while Brazil has moved mainly toward oil, natural gas, and biomass energy production and consumption, and for Russia, the production and consumption of oil, gas, coal account for a large proportion of energy structure. The energy production and consumption structure of these two countries are significant different from those of China and India. On the other hand, each country of the BRICs has experienced failure and success, and for these reasons, experiences and lessons can be summarized from previous energy policies based on the comparative analysis of renewable energy policies evolution in the BRICs. Also, the research has reference value for building future renewable policies framework in China.

2. Literature review

Currently, the research work related to the evolution of the renewable energy policies of the BRICs can be categorized as follows.

2.1. Renewable energy policy evolution in Brazil

Most research on Brazil renewable energy policy evolution is related to the evolution of biomass energy policies. In the discussion of Brazil energy trends and objectives, Howard et al. investigated five promotional policies of renewable energy, namely, expanding the production and the application of ethanol fuel, stimulating in CHP systems using bagasse and other sugarcane products, grid-connected wind power, and renewable energy use in off-grid applications, and improving in the efficiency of freight transport [1]. Wu reviewed Brazil's biomass policies since the 1950s in the 20th century, which included special credit of biodiesel, the addition proportion of biodiesel, the joint innovation of industries, universities and research institutes, establishment of technology networks, alcohol scale, and international cooperation [2]. Yu and Zhou, analyzed renewable energy policies from the angle of technology supplies and diffusion of biomass energy [3,4]. By the comparison of renewable policies as financial subsidies, R&D incentives, among Brazil and institutional settings, Xiong and Wu indicated that implementation detailed rules, tax preference, market-oriented operation and R&D incentives offered inspirations for China renewable energy development [5]. Amaro et al. explored the best strategy of maintaining the high share of renewable energy resources in the Brazilian electric power system, and assessed policies of the Alternative Sources Incentive Program and annual energy purchase and sale auctions [6].

2.2. Renewable energy policy evolution in Russia

Research on Russian renewable energy policy evolution is insufficient, and limited literatures are either focused on policies of renewable energy technology diffusion and transfer such as the study of Eric [7,8], or emphasizing the evolution of the energy strategy. Take, for example, the analysis on energy strategy evolution from 1992 to 2003 by Zhu and Shi [9] and Zhang [10], and discussion on three phrases of Russia Energy Strategy by Sun [11]. The literature work was not relevant to renewable energy policy evolution.

2.3. Renewable energy policy evolution in India

The current studies include: (1) *Wind energy policies*. Fang and Zeng presented wind energy incentives, which were depreciation policies, tax exemption of electricity sales, differential tariff policies of import fans, and evaluated the implementation effects [12]. (2) *Biodiesel policies*. Yang gave importance to India hybrid gasoline experimentation and biodiesel procurement policies from 1977 to 2005 [13]. (3) *Hydropower policies*. For the development of India hydropower, the literature was concerned about attracting private and foreign investment, simplifying technology transfer licensing, and other policies starting in 2003 [14]. However, the policy implementation effects were not evaluated. (4) *PV technology policies*. Attaching importance to two perspectives of PV technology supply and diffusion, Bhargava presented R&D and solar lighting, power grid interactive photovoltaic systems, water pumping project [15]. (5) *Comprehensive policies*. Other scholars, such as Zhang, Bhattacharya and Chinmoy, noted the evolution of policies of biomass gasification furnace, wind, biogas, solar energy and small hydropower. Nevertheless, slightly different from Zhang's research, Bhattacharya and Chinmoy stressed international comparisons among India and other countries [16,17].

2.4. Renewable energy policy evolution in China

Research focused on two aspects: first, assess implementation effects based on types of policies. Chinese Energy Development Strategy and Policy Research Report Force classified implementation of Chinese major energy policies into three different levels and assayed implementation effects of policies as "Comprehensive Energy Strategy and Policy Evaluation", "Resources", "Power", "Rural Energy and New Energy", "Energy Efficiency and Conservation", "Environmental, Safety and Health", "Reform", "Economic Policy" and "Opening up", evaluating renewable energy program, hydropower and other renewable energy policies. Also the Report Force set renewable energy goals to be met by 2020, which were "meeting international standards for most renewable energy technologies, reducing costs and implementing commercialization, propelling the change of rural fuel structure, and solving the power shortage of remote areas thoroughly" [18]. More scholars were concerned about renewable energy technology policies. Xie et al. and

Wang appraised China renewable policies in the 1980s, 1990s, and 21st century, which involved tax incentives, subsidies for operating expenses, R&D and projects, and proposed technology supply and diffusion policies [19,20]. Zhang et al. categorized the renewable policies as laws and regulations, economic incentives, technological R&D, industry support and government demonstration projects, based on which the authors analyzed defects of renewable energy policies and offered suggestions as policy coordination, regional policy innovation, the clean development mechanism and process management [21].

Second, analyze renewable energy evolution policies according to energy types: (1) *Biomass policies*. Wang, Ma, Zhang discussed biomass policies evolution, in which emphasis was put on ethanol promotion, vehicle ethanol standards, subsidies for renewable energy technologies and industrial support [22]. (2) *PV technology and application policies*. Hong et al. commented on China's photovoltaic power generation technology and application policies after the 1992 United Nations Global Summit on Environment and Development, indicating that government efforts to reduce the production cost of crystalline silicon module engendered the emergence of PV systems, and opened up the markets innovative designs and products market [23]. (3) *Wind power policies*. Based on evaluating wind power laws and mandatory policies, fiscal incentives, grid integration and R&D policies, Cuiping analyzed wind power industry development and commercialization barriers from the aspects of wind turbine technology, private capital incentives, transmission lines and supporting infrastructure, etc. [24]. Forming a different angle on wind power industry, Yingqi and AriKokko discussed national and provincial policies from the aspects of grid-connected electricity price, structure, compulsory-purchase policies, technology R&D starting in 1988 [25]. (4) *Household biogas policies*. Yu studied financial subsidies and renewable energy laws in the 21st century, and pointed out that follow-up service, biogas management, straw fermentation, cold fermentation technology to some extent, limited the use of household biogas [26]. (5) *Comprehensive policies*. A few scholars such as Zhao and Xiong analyzed comprehensive incentive policies performance of wind power, solar, biomass and hydropower industry with an emphasis on existing problems [27].

Compared with the above studies, although there is no detailed analysis on renewable energy policies revolution, Li and Zhuang summed up the characteristics of policy evolution, which were "a process of transformation from unitary and a biased projects to systemic and integrated policies, a process of transformation from qualitative provisions to quantitative objectives" [28].

In summary, current research mainly analyzes renewable energy policies qualitatively, and less focuses on policy performance evaluation; furthermore, the implementation effects of renewable energy policies are not only embodied as the growth of renewable energy production, but also the increase in renewable energy consumption with the process of technical diffusion. Finally, there is a lack of comparison analysis among the BRICs' renewable energy policies. Based on the analysis, this paper attempts to establish indicators as renewable production and consumption to evaluate renewable energy policy evolution in the BRICs quantitatively with the BP break test.

3. Methods

BP break test can be used to examine both the existence of sub-trend stationary process around structural breaks and the number of breakpoints. If a time series is sub-trend stationary process around structural breaks, the impact of structure breaks exerts lasting influence on economic aggregate, and changes its growth path.

Renewable energy policies in the Bric countries have experienced several structural changes, and the indicators reflecting energy strategy performance could vary with the major energy strategy adjustments. Therefore BP break test is applicable to make empirical analysis on energy strategy evolution.

Consider the linear regression model with m breaks as follows:

$$y_t = x_t'\beta + z_t'\delta_1 + u_t, \quad t = 1, 2, \ldots, T_1; \tag{1}$$

$$y_t = x_t'\beta + z_t'\delta_1 + u_t, \quad t = T_1 + 1, T_2 + 2, \ldots, T_2; \tag{2}$$

$$y_t = x_t'\beta + z_t'\delta_{m+1} + u_t, \quad t = T_m + 1, T_m + 2, \ldots, T; \tag{3}$$

where y_t is the observed dependent variable at time t; x_t and z_t are vectors of covariates; β and δ_j ($j = 1, 2, \ldots, m + 1$) are the corresponding vectors of coefficients; u_t is the disturbance at time t; $T_1, T_2, \ldots, T_m$ are break points. Note that this is partial structure change model. When $x_t = 0$, we obtain a pure structure change model where all the coefficients are subject to change, the multiple linear regression system can be expressed in matrix form as:

$$Y = X\beta + \overline{Z\delta} + U \tag{4}$$

where $Y = (y_1, \ldots, y_T)'$, $X = (x_1, \ldots, x_T)'$, $U = (u_1, \ldots, u_T)'$, $\delta = (\delta_1', \delta_2', \ldots, \delta_{m+1}')'$, and $\bar{Z}$ is the matrix which diagonally partitions Z at $(T_1, T_2, \ldots, T_m)$. Based on this, Bai and Perron proposed four tests to determine the exact number of breakpoints and time of occurrence [29]. First consider the sup-wald type of no structure break ($m = 0$) versus the alternative hypothesis that there are $m = k$ breaks. Define

$$F_T(\lambda_1, \lambda_2, \ldots, \lambda_k, q) = \frac{1}{T}\left|\frac{T-(k+1)q-p}{kp}\right| \widehat{\delta}'R'(R\widehat{V}(\widehat{\delta})R')^{-1}R\widehat{\delta} \tag{5}$$

where p and q are the number of dependent (or explanatory?) variables as x_t and z_t, respectively. $\lambda_i = T_i/T$, $(R\delta)' = (\delta_1' - \delta_2', \ldots, \delta_k' - \delta_{k+1}')$, and $\widehat{V}(\widehat{\delta})$ is an estimate of the variance covariance matrix of $\widehat{\delta}$ that is robust to serial correlation heteroscedasticity. In general, the researchers have not pre-assumed that the number of specific breakpoints of breaks, thus Bai and Perron provided two tests of the null hypothesis of no structural break against an unknown number of breaks given upper bound M. Construct statistics

$$\text{UD max} F_T(M, q) = \max_{1 \le m \le M} F_T(\widehat{\lambda}_1, \ldots, \widehat{\lambda}_2, \widehat{\lambda}_m; q), \tag{6}$$

and

$$\text{WD max} \;\; F_T(M, q) = \max_{1 \le m \le M} \frac{c(q, \alpha, 1)}{c(q, \alpha, m)} F_T(\widehat{\lambda}_1, \widehat{\lambda}_2, \ldots, \widehat{\lambda}_m; q) \tag{7}$$

where $\widehat{\lambda}_i = \widehat{T}_i/T (i = 1, 2, \ldots, m)$, $c(q,\alpha,m)$ is the asymptotic critical value of $\max_{1 \le m \le M} F_T(\widehat{\lambda}_1, \ldots, \widehat{\lambda}_2, \widehat{\lambda}_m; q)$ for a significance level α. The three tests are mainly used to determine the breaks existence of time series. On this basis, Bai and Perron [30] proposed a test for l versus $l + 1$ breaks, that is

$$\sup F_T\left(l + \frac{1}{l}\right) = \frac{\{S_T(\widehat{T}_1, \ldots, \widehat{T}_l) - \min\limits_{1 \le i \le l+1} \inf\limits_{\tau \in \Lambda_i, \eta} S_T(\widehat{T}_1, \ldots, \widehat{T}_{i-1}, \tau, \widehat{T}_i, \ldots, \widehat{T}_l)\}}{\widehat{\sigma}^2} \tag{8}$$

$$\begin{aligned} \sup \;\; F_T\left(l + \frac{1}{l}\right) &= \{S_T(\widehat{T}_1, \ldots, \widehat{T}_l) - \Lambda_{i,\eta} \\ &= \{\tau, \widehat{T}_{i-1} + (\widehat{T}_i - \widehat{T}_{i-1})\eta \le \tau \\ &\le \widehat{T}_i - (\widehat{T}_i - \widehat{T}_{i-1})\eta\} \end{aligned} \tag{9}$$

$\widehat{\sigma}^2$ is the consistent estimator of residual item variance for the null hypothesis, η is the minimum limit to each sub-interval length for ensuring test effectiveness, and generally set $\eta = 0.05T$.

Table 1
BP break test results (Brazil).

BP test	$\mathrm{SupF}_T(1)$	$\mathrm{SupF}_T(2)$	UDmax	WDmax
ln REP	90.93***		90.93***	90.93***
ln REC	46.12***	–	46.12***	46.12***

*** 1% significant level.

4. Empirical analysis

4.1. Variables and data

In accordance with the actual situation of renewable energy policies in the BRICs, we study the effects of renewable energy evolution by choosing renewable energy production, renewable energy consumption as variables.

According to the study of Chinese Energy Development Strategy and Policy Research Report [18] and Xu [31], China's energy strategy started from the reform and opening up, and was marked by the slogan: "Energy is the most important economic issues" proposed by Deng Xiaoping in 1980 and the central government's slogan: "lay equal stress on development and conservation, give priority to energy conservation for the short term". Therefore, to compare the performance of China renewable energy policy evolution with that of other countries, this paper unified the period from 1980 to 2007. The sample data was acquired from the EIA official website of the United States. As for data processing, we take natural logarithm of the two variables, variables denoted by ln REP, ln REC, respectively.

4.1.1. Empirical analysis results

Empirical analysis results indicate no break for time series of renewable production in Russia, while a series of renewable production and consumption are characterized as segmented trend stationary processes around one or two structural breaks in Brazil (Tables 1 and 2), India and China. At 5% significance level, there are 1, 1 breaks for Brazilian renewable energy production and consumption.

Segmented trend stationary functions of Brazilian time series are expressed as:

$$\ln \mathrm{REP}_t = 1.276 + 0.100t - 1.856DU_{t1} + 0.072tDT_{t1} \tag{10}$$

$$\ln \mathrm{REC}_t = 1.228 + 0.099t - 1.906DU_{t1} + 0.072tDT_{t1} \tag{11}$$

where DU_t and DT_t denote mean and trend dummy variables of structural breaks. $DU_t = 1(T > t)$, $DT_t = (t-1)1(t > 1)$, and for (10) and (11) denote stationary functions of renewable energy production and consumption at different time respectively.

Both breakpoints of renewable energy production and renewable energy consumption appeared in 2001 (Fig. 1), and coefficients of trend dummy variables are positive, indicating that energy policies in 2001 had long-term effects on renewable energy production and consumption, improving the variables' growth rate.

In practice, a combination of subsidies, setting quotas, unified purchase fuel ethanol had been adopted since 2000. The policies had three characteristics: (1) Compulsory spread of biomass energy by legislation. Brazil formulated "Ethanol Program" in 1975 to encourage R&D, speed up developing ethanol fuel vehicle and strongly promote the application of ethanol fuel technology, and

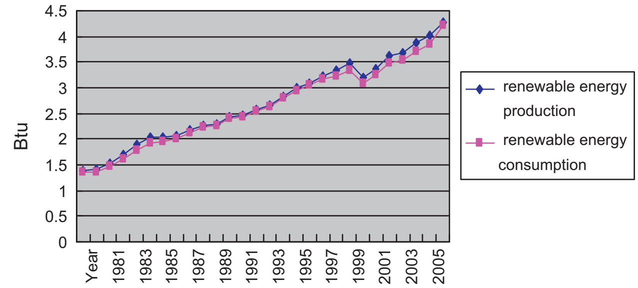

Fig. 1. The time series of renewable energy production and consumption in Brazil.

then, enacted policies of 25% volume ratio of ethanol addition to gasoline in 2002. Such measures spurred the proportion of ethanol in alcohol gasoline to rank the first in the world, popularizing ethanol fuel effectively. (2) Put the efforts on biomass and other renewable energy power generation projects. Between 1997 and 2000, bagasse and waste were harnessed to co-generation in biomass project which implemented by Brazilian Ministry of Science and Technology. In 2002, a policy known as PROINFA announced expansion of the generation of wind energy, biomass and small hydropower, and one of PROINFA objectives was that renewable energy generation would accounted for 10% of total generation capacity by 2002.With the implementation of this policy, a great amount of wind power plants were established in the early of 2002 and 2003, improving the production of renewable energy to some extent. (3) Emphasize the integration of biomass energy industrial chain. Since the introduction of flexible fuel vehicles were introduced, Brazil followed the path of "producing sugar cane -organizing experts to analyze-deploying the proportion of ethanol-providing the consumers with tax incentives" to meet the market demand. Based on abundant sugar cane, the Brazilian government organized experts to conduct experimental and demonstration, requiring the manufactures to improve engines and other equipments, and claiming the term of government to make the initial demonstration. In addition, the government prohibited wholesale companies and petrol stations from tampering with the proportion of ethanol. To stimulate consumer demand, the government tilted the tax policies toward gasoline at the end of industrial chain. According the policies, consumers could choose between gasoline and alcohol, however, the price was 2.67 reais per liter for regular gasoline, and 1.69 reais per liter for alcohol respectively. Both should pay 11.85% of the federal tax; but the state tax was only 12% for alcohol, a striking contrast to 25% for gasoline, and furthermore, 0.28 per liter of gasoline special tax should be paid.

$$\ln \ REC_t = 2.632 + 0.044t - 0.286DU_{t1} - 0.020tDT_{t1} \tag{12}$$

There was no break for time series of renewable production in Russia, results showed that renewable energy policies did not impact energy production significantly in the long-term. The break point of renewable energy consumption appeared in 1996 (Tables 3 and 4), and coefficients of intercept and trend dummy variables are both negative, presenting unnotable success of renewable policies. While in practice, the first systematic energy policy The Concept of Russian Energy Policy in New Economic Conditions for Russia was formulated in 1992 after its independence. Followed by Main Directions of Energy Policy of the Russian

Table 2
The number of breaks at 5% significant level (Brazil).

Break time	T_1/year	T_2/year
ln REP	2001	–
Confidence interval (95%)	2000–2002	–
ln REC	2001	–
Confidence interval (95%)	1999–2002	–

Table 3
BP break test results (Russia).

BP test	$\mathrm{SupF}_T(1)$	$\mathrm{SupF}_T(2)$	UDmax	WDmax
ln REC	26.85***	–	26.85***	26.85***

*** 1% significant level.

Table 4
The number of breaks at 5% significant level (Russia).

Break time	T_1/year	T_2/year
ln REC	1996	–
Confidence interval (95%)	1995–1998	–

Table 5
BP break test results (India).

BP test	$SupF_T(1)$	$SupF_T(2)$	UDmax	WDmax
ln REP	228.13***	15299.50***	15299.50***	19201.46***
ln REC	87.65***		171.38***	171.38***

BP test	$SupF_T(2/1)$	$SupF_T(3/2)$
ln REP	12291.55***	–

*** 1% significant level.

Federation until 2010 and Energy Strategy of Russia in 1995. To implement energy policy within the framework of integrated energy outline, Russia introduced a number of specific renewable energy outlines, which involved Program for Supporting Fuel and Power Complex, Alternative Energy Program, Non-conventional Renewable Energy Application Program and Environmental Energy Technology Program et al. However, Russian energy strategy was aimed at overcoming the energy crisis, improving energy efficiency and energy reserves during the Yeltsin era rather than the development of renewable energy; moreover, Russia lacked technology promotion agencies, information and demonstration experience, long-term commercial financing and a number of direct and indirect subsidies on energy prices. Therefore, energy strategy characteristics and defects of renewable energy technology commercialization and marketing impeded renewable energy consumption.

$$\ln\ REP_t = 0.413 + 0.113t + 0.022DU_{t1} - 0.08tDT_{t1} \quad (13)$$

$$\ln\ REP_t = 0.435 + 0.033t - 1.863DU_{t2} + 0.113tDT_{t2} \quad (14)$$

$$\ln\ REC_t = 0.461 + 0.025t - 2.378DU_{t1} + 0.098tDT_{t1} \quad (15)$$

For India, two breakpoints of renewable energy production appeared in 1982 and 2002, respectively (Tables 5 and 6). Intercept dummy variable coefficient of the first break is positive, while the trend dummy variable coefficient is negative; the second break is contrast with the former. Only one break point existed for the time series of renewable energy consumption, and also appeared in 2002. Structure change of renewable energy production and consumption indicates that energy policies in the early 1980s provided positive impact on renewable energy production in the short-term, whereas provided negative impact in the long-term. Renewable energy policies about in 2002 produced desirable results, improving the growth of renewable energy production and consumption. In terms of renewable energy institutions, India established "Complementary Energy Commission", followed by "Non-conventional Energy Board" in 1982 for the promotion of renewable energy development. In terms of renewable energy planning and projects, India launched "National Plan for the Development of Biogas" from 1981 to 1982, and "National Programs to Improve Stoves" (NPIC) to promote efficiency in the use of biofuels, reduce forest resources pressure and reduce indoor air pollution. However, renewable energy policies were still imperfect in the early 1980s, manifested profoundly by the lack of effective participation of the private sector, renewable energy R&D and policy support for commercialization and demonstration projects. The corresponding R&D and commercialization policy began after the mid-1980s, for example, the subsidies for the biogas project were formulated in 1985, and Indian Renewable Energy Development Agency (IREDA), which engaged in renewable energy research and development, commercialization and implementation of demonstration projects was established in 1987. Moreover, the Indian private sector could participate in wind power until the announcement of "Private Power Policy" in 1991.

Table 6
The number of breaks at 5% significant level (India).

Break time	T_1/year	T_2/year
ln REP	1982	2002
Confidence interval (95%)	1982–1983	2001–2003
ln REC	2002	
Confidence interval (95%)	2001–2003	

Table 7
BP break test results (China).

BP test	$SupF_T(1)$	$SupF_T(2)$	UDmax	Wdmax
ln REP	292.84***	–	292.84***	292.84***
ln REC	270.37***		270.37***	270.37***

*** 1% significant level.

Table 8
The number of breaks at 5% significant level (China).

Break time	T_1/year	T_2/year
ln REP	1993	–
Confidence interval (95%)	1992–1994	
ln REC	1993	
Confidence interval (95%)	1992–1994	

India perfected the renewable policies from 2001 to 2003. Energy Conservation Law was formulated in 2001, followed by The Electricity Act in 2003. In addition to perfecting the law system, India developed the energy policy in favor of commercialization and private sector participation. For example, India made structural reforms in its energy sector to encourage private capital' s participation in the energy industry. In 2000, the Ministry of Petroleum and Natural Gas executed an ethanol-blended petrol plan in major sugar-producing states such as Maharashtra and Uttar Pradesh, etc. In 2001 ethanol blended gasoline was sold in 300 retail outlets and great success was achieved in ethanol blend gasoline tests. Based on this, the Ministry of Petroleum and Natural Gas pilot extended to Andhra Pradesh, Punjab and Uttar Pradesh and other regions in 2002. Thus, India renewable energy policies near the second breakpoints enhanced renewable energy production and consumption effectively.

(16)$\ln REP_t = 0.742 + 0.101t - 5.731DU_{t1} + 0.281tDT_{t1}$

$$\ln\ REC_t = 0.418 + 0.090t - 5.924DU_{t1} + 0.289tDT_{t1} \quad (17)$$

The break points of Chinese renewable energy appeared in 1993 (Tables 7 and 8). Intercept dummy variable coefficient of the first break is negative, while the trend dummy variable coefficient is positive, indicating that the State strategy in 1992 had long-term effects on renewable energy by supporting small hydropower development and increasing expenditure on rural energy construction, which increased the growth rate of renewable energy production proportion accounted for total energy production.

5. Conclusions

To summarize, no break for time series of renewable production in Russia, while series of renewable production and consumption are characterized as segmented trend stationary processes around one or two structural breaks in Brazil, India and China. Renewable policies in Brazil and China have long-term positive effects on renewable energy production and consumption, improving the two variables' growth rate. The time series structure change of Indian

renewable energy production is complicated, and the long-term impact of energy policies on renewable production is the contradictory at the two breakpoints. Russian renewable policies are not working, reducing the renewable energy consumption growth in the long-term. For the BRICs, only Russian renewable energy policies have the long-term negative effects on renewable energy consumption.

The policy implications of empirical analysis for China are as follows:

(1) To promote renewable energy compulsorily based on industrial planning. In view of renewable energy policies of Brazil and India, the two countries promoted ethanol blended gasoline by legislation or market force, producing marked effects. Compared with Brazil and India, China put much efforts on industrial planning of renewable energy, and laid emphasis on technical R&D, credit and market mechanism, while overlooking mandatory renewable energy promotion policies which should be paid attention to.
(2) To develop biomass energy on the basis of comparative advantages, besides the wind power and solar energy. China successively promulgated Renewable Energy Law, Middle and Long Term of Renewable Energy Development, Management Regulations for Electricity Generation from Renewable Energy, Tentative Management Measures for Price and Sharing of Expenses for Electricity Generation from Renewable Energy, Measures on Dispatch of Energy Saving and Power Generation (for Trail), the 11th Five-year Plan on Renewable Energy in support of equipment localization, wind power grid, franchise tender and et al. For solar energy policies, China adopted subsidy policies, and Ministry of Finance, Ministry of Science and National Energy Board launched Golden Sun Demonstration Project to propel solar energy development. In spite of that, the comparative disadvantages of machinery and equipment relative to developed countries resulted in the dilemma of wind power and photovoltaic' development. Similar to wind and solar resources potential, China is abundant in biomass energy, too, and key technologies of subdivided industries are of less disadvantages. Some of the biomass energy technologies such as biomass solid briquette technology, non-food biomass alcohol production technology are in a leading position in the world. Therefore, China may consider propelling the development and utilization of biomass energy based on comparative advantages.
(3) To strengthen the system support of the technology diffusion from the perspective of integration of industrial chain. Being lack of technology demonstration and popularization, raw materials dispersion and purchasing market confusion and other issues, China should learn from the experiences and lessons of Brazil, India and Russia, attaching importance to industrial chain integration.

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